TEST REPORT

A Portable Burn Pan for the Disposal of Excess Propellants

ESTCP Project ER-201323

NOVEMBER 2015

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14. ABSTRACT

Munitions for indirect fire weapon systems are issued with a full complement of propellant charges. Excess charges are typically not turned in and are destroyed by open burning as part of the unit's training. Burning of the charges can result in up to 20% of the propellant remaining in the form of residues on the ground. A portable propellant burn pan system was design and demonstrated as part of Environmental Security Technology Certification Program (ESTCP) Project ER-201323 to enable safe, environmentally effective training of the military. Tests have demonstrated a 99.98% reduction in combustible mass of the charges, less than 0.001% of the energetics in the burn pan ash, energetics concentration of less than 0.5% in the residual ash, and no detectable difference in energetics in the soil surrounding the pan after burning over 450 kg of charges. Performance objectives for the burn pan device were met or exceeded by the final system design.

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TEST REPORT

CRREL PORTABLE PROPELLANT BURN PAN

TEST AND DEMONSTRATION OF FINAL VERSION OF PAN

DONNELLY TRAINING AREA, ALASKA
AUGUST 2015

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25 November 2015

Cover image: Burning of 90 kg M1 artillery propellant, Firing Point Sally, Donnelly Training Range, Ft. Wainwright (Delta Junction), AK, 14 August 2015. *(MR Walsh, USA CRREL)*

TEST REPORT

CRREL Portable Excess Propellant Burn Pan
Howitzer Training Unit Model – Final version
Firing Point Sally, Donnelly Training Area, AK
13 – 14 August 2015

PARTICIPANTS

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Objectives: The objectives of this test were as follows:

- Conduct a test burn of excess howitzer propellant in the updated burn pan
- Obtain performance data for pan (weight, time to burn, capacity)
- Obtain and analyze samples of residues in pan and on soil to evaluate burn efficiency
- Demonstrate burn pan to Donnelly Training Area ITAM Environmental Manager, Range Operations officers, and officers and troops from the 2/377th PFAR/4th BCT/25th ID
- Have training unit do a complete burn operation with the pan
- Obtain feedback from training unit, Range, and ITAM program coordinator

Background

Munitions for indirect fire weapon systems are issued with a full complement of propellant charges, ranging from four to over 10 individual charges per round. Charge loads are varied in accordance to the desired ballistics of the fired projectile and the state of the weapon system. Excess, unused propellant charges result from the reduced charge load required for operation of a "cold" weapon system or firing at less than maximum range. Excess charges are typically not turned in and are destroyed by open burning as part of the unit's training.

The burning of excess propellant charges is typically carried out in one of three manners: Transportation to a central burn facility where specialists dispose of the charges, transportation to distributed fixed burn pans where a limited number of trainees dispose of the propellants, or burning of the charges by the training troops on the ground near the firing positions. The first option is cleanest as trained personnel conduct the burn in a generally well-maintained burn pan and can collect the residues for disposal. However, the soldiers do not gain experience burning the propellant as they would in combat, and there are risks associated with transporting the propellant charges over long distances. The pans are also not specifically designed for the disposal of propellants and are not as efficient as they could be. They also require a prepared pad area for

safety during the burn. The second option affords the troops with the opportunity to conduct the burn as part of their training, but transportation of the propellant limits the number of soldiers involved. Maintenance of remote fixed pans can be problematic, as can be the collection of post-burn residues. There is also little oversight of the training by unit officers. Burning of excess propellants on the ground is still conducted on many training ranges, giving the troops the most realistic and valuable training experience associated with live-fire training. However, burning on the ground can result in up to 20% of the propellant remaining in the form of residues on the ground following a burn, and these residues are not collected for disposal. The residues contain toxic materials that can harm the environment and human health. The presence and accumulation of energetic compounds at firing points can jeopardize the continued use of the range through migration to surface and ground water. A better alternative to these options was therefore sought.

Under US Department of Defense Strategic Environmental Research and Development Program project ER-1481, the US Army Cold Regions Research and Engineering Laboratory CRREL) and Defence Research and Development Canada–Valcartier (DRDC) examined alternatives to the then-current propellant burning practices. The Canadian researchers at DRDC concentrated on optimizing the fixed burn pan concept while CRREL worked on developing a portable burn pan that can be transported to the firing points where training occurs. Working together, a general design concept was developed and tested, first using a series of the fixed Canadian pans, then with the portable pans developed by CRREL. The Canadian design has been finalized and its use is part of training and range management doctrine in Canada. The portable pan was developed through the first two prototype models, performing well in both cases. In 2013, CRREL was awarded project funding by the Environmental Security Technical Certification Program through Project ER-20323 for the completion of the development and the demonstration of the portable burn pan concept. A pan designed for howitzer training units has been designed and tested, meeting all the criteria set out by CRREL and ESTCP. A smaller unit was designed for mortar training units and has also been successfully demonstrated. This report describes the testing of the final version of the howitzer training burn pan in association with an artillery unit training exercise at the Donnelly Training Area, Delta Junction, AK (DTA). Results are compared to previous testing with propellant burns.

Methods

A burn pan was fabricated at CRREL based on improvements to the previous prototypes. The overall goal for the new design was to increase usability of the pan based on feedback from the previous four tests. Design improvements were made to facilitate loading and ignition of the propellant. It is a simple, self-contained design with a minimum of parts **(Figure 1).**

The burn pan consists of three assemblies. The base is the main component. It is a welded aluminum fabrication approximately 1-m x 2-m x 0.3-m deep on 30-cm high legs. It has handles placed on both sides of all four corners for lifting and placement of the assembled unit. A stainless steel false bottom fits into the base. It has perforated stainless sides that contain the charge bags and act as a guide for loading the charges. The false bottom serves to protect the aluminum base from the heat of deflagration of the propellant charges. The stainless bonnet fits onto the top of the pan and helps contain the burn and any debris, such as charge bag fragments, from being ejected

from the pan without constricting the burn. The base has a retractable ignition trough (slider) at one end that is used to prime the propellant charges for ignition. Recommended auxiliary equipment for the burn pan includes a tarp with tie-downs for storage and a flat-bottomed scoop for collection of the burn residues. These were provided to with the pan for this test. Fire suppression equipment such as a Class A fire extinguisher or backpack firefighting pumps should be supplied by the appropriate entity.

Figure 1: Briefing artillery unit on burn pan theory and operation.

The site chosen for the test is located on Firing Point Sally. FP Sally is a heavily used multi-purpose range that has had extensive surface soils munitions constituents characterization conducted on it since 2000. Yearly assessments of the range are conducted by CRREL for USARAK and the site was also used for an ESTCP project on sampling optimization (ER-201329). Arrangements were made for conducting the burn pan test at DTA with Mr. Steve Thurmond, the USARAK Range Manger for DTA. Mr. Joe Clark of Range Control assisted us in the field. The 2/377th PFAR, Joint Base Elmendorf-Richardson (JBER), agreed to train on the burn pan with excess propellant from their concurrent training exercise. The pan components were weighed prior to transport to the test site.

The firing point is a grassy open area browsed by the local American Bison herd. A location was chosen for the burn pan and baseline soil samples were taken on 13 August 2015 to characterize the site prior to the test burns. An area from 0 to 3-m from the outer burn pan outline was sampled in triplicate with the CRREL multi-increment (MI) sampling tool using a 3-cm coring bit set at 3-cm depth. An additional area from 3 to 6 m from the pan location center point was also sampled in the same manner. Weather was initially calm with light overcast and no precipitation.

After inspecting the area, CRREL and USARAK transported and placed the burn pan at the test location **(Figure 2)**. Excess propellant charges were collected from the howitzer batteries by the

artillerymen of the 2/377th following the cessation of activities on 13 August. On 14 August, the charges were transported to FP Sally and weighed and divided by CRREL into six loads for the burns **(Table 1)**. Burn loads were limited to 90 kg because of the dry surface conditions, which could result in a grass fire.

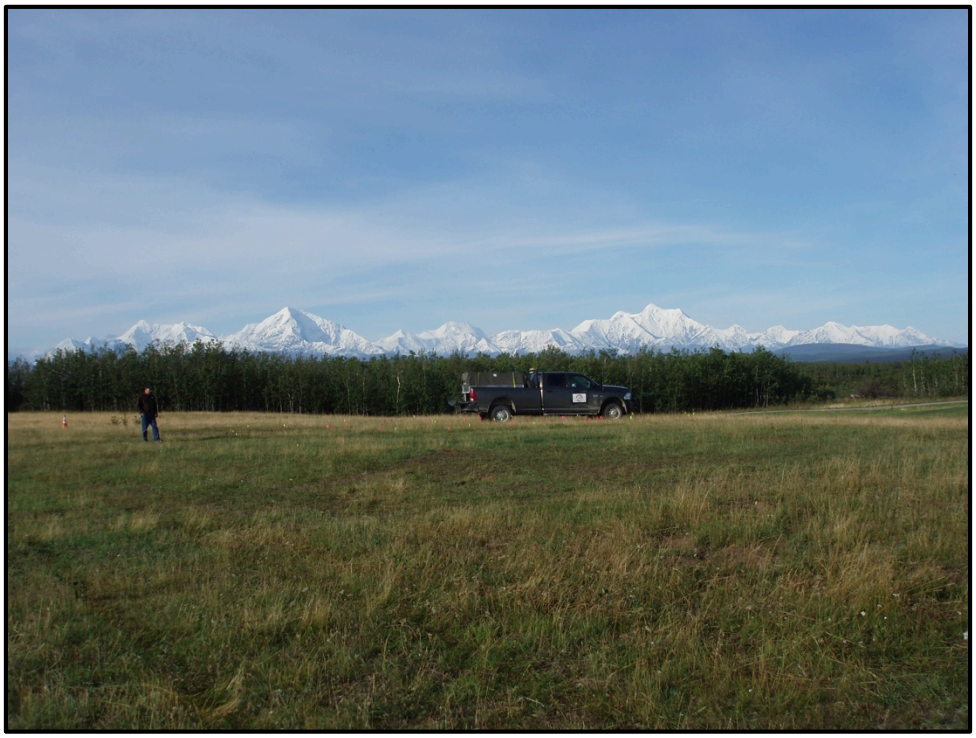


Figure 2. Burn pan test site. Note pan in back of truck.

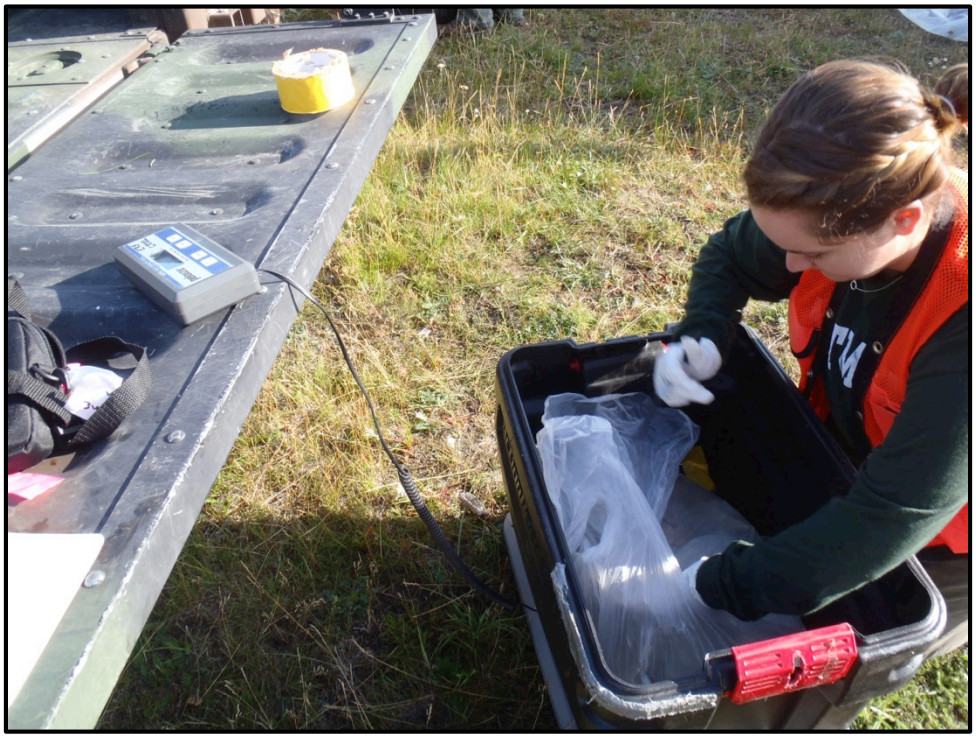


Figure 3: Weighing propellant charges prior to burn tests.

Table 1: Propellant loads for burns

Load	Mass (kg)
1	39.4
2	88.9
3	83.4
4	79.1
5	86.5
6	81.1
	458.4 kg Total

All burns were conducted by the 2/377th under supervision from CRREL. The pan was loaded with propellant charges by the soldiers and evenly distributed in the false bottom **(Figure 4)**. One charge bag was slit open and some of the grains used to prime the slider. At the internal end of the slider (within the pan), the remaining propellant grains as well as those from several other opened bags were piled over the slider onto unopened bags surrounding the end of the slider **(Figure 5)**. The bonnet was placed on the pan and inspected to ensure it fit properly on the base. The propellant was then initiated through the slider by igniting the propellant grains with a butane lighter **(Figure 6)**. Following the cessation of the burn, the pan was inspected to ensure completion of the process. When the handles on the bonnet were cool enough to touch, the bonnet was removed, the ash checked for embers, and the next load of propellant put in the pan. A photographic illustration of the sequence is presented in **Appendix A.**

Figure 4. Loading propellant charges in burn pan.

At the end of the tests, two sets of triplicate MI soil samples were taken from the same areas as the baseline samples. The bonnet was removed and the residues collected and bagged for later processing and analysis at CRREL. The active test and demonstration was then complete.

Figure 5. Placing propellant grains at end of slider to initiate burn.

Figure 6. Initiating propellant in slider.

The test was observed by officers and enlisted personnel of the 2/377th PFAR, a DTA Range Officer, and the Integrated Training Area Management program environmental officer. Following the burn, each party was solicited for input on the process. The pan was then turned over to the DTA Range officer for future use. The unit commander requested continued use of the pan so that he could train more artillerymen on its use and in the process of burning of the excess propellant charges.

Soil samples and the residues were transported to CRREL for processing and analyses. Samples were set out to air dry, the two sets of samples (pre- and post-burn) separated from each other to prevent cross contamination. When dry, the soil samples were weighed, separated into <500-g lifts, and ground for five 60-second periods with a puck mill (LabTech Essa Model LMP-2) to obtain the required particle size without degrading the energetic compounds. The ground lifts for each type of soil sample were combined, stirred, and subsampled using MI sampling (40 increments) to obtain the 10-g subsample for analysis. The subsamples were placed in a 60-mL (2 oz) wide-mouth amber jars along with 20 ml of solvent (acetonitrile [AcN]) and shaken for 18 hours on a New Brunswick Scientific Innova 2100 platform shaker oscillating at 150 opm**.** Analyses were conducted on a Thermo Finnigan SpectraSystem 2000 high-performance liquid chromatograph with an ultra-violet detector (HPLC-UV) in accordance with EPA Method 8330b. The analytes of concern for the M1 single-base propellant were 2,4- and 2,6-dinitrotoluene (DNT). We did not analyze for nitroglycerin, which was likely present because of small arms training that also occurs at the site. There was no lead foil in the propellant bags burned during this test, although all the charges contained lead carbonate as part of the M1 propellant formulation.

The pan residues were weighed and processed separately from the soil samples. The air-dried residues were weighed, extracted with AcN in their entirety, and analyzed in the same method as the soils. A qualitative concentration of the Pb in the soil and the ash in the pan was assessed using X-ray florescence.

Quality Assurance (QA)

Several QA activities were programmed into the testing and analysis. In the field, triplicate soil samples were taken before and after the burns. Triplicate analyses were conducted on one of the ground MI samples and eight replicates on another. A small study of the consistency of increments was conducted using the mean mass of the increments for each sample. Soil and sand blanks were run to determine if carryover was occurring. Matrix spike duplicates were run to determine if there were any interferences occurring during elution of the analytes from the soil. Duplicate laboratory control spike were run to determine response and recovery of the analytical instrument. Infrared spectrometry was used to determine the system temperature throughout the burn process.

Results

Pan Weight

The combined mass of the howitzer training unit (HTU) burn pan is 128 kg. This is slightly higher than project objective for the total mass of the HTU burn pan of less than 120 kg. The bonnet was made more durable while eliminating hazardous sharp edges by using a frame of stainless steel angle irons, resulting in a gain of mass of 12 kg. The mass of the pan base is 43 kg, the false bottom 43 kg, and the bonnet 42 kg, all well under the 50 kg individual component weight target set out in the ESTCP requirements. Four soldiers easily maneuvered the complete unit, and individual components were easily handled by two. Maximum lifting height was 1 m in and out of the transport vehicle. Some problems were encountered by shorter individuals removing the bonnet from the base of the pan. This and the weight issue will be addressed in a final design modification.

Test Conditions

Climatic conditions were good during the burns. There was a light overcast with intermittent light wind. The wind picked up a bit over the course of the testing but remained under 2 m/s during the tests. The area was quite dry, so we limited the burns to 90 kg rather than the target 120 kg to avoid uncontrolled burning of the grass. As it turned out, the radiant heat of the burn and lofted burning charge bag pieces burned a limited area around the pan location (Figure 7). The air temperature was ≈15°C, varying depending on cloud cover. The clouds increased over the course of the testing.

Figure 7. Burn pan location (green grass) surrounded by area affected by the heat of the burns.

Cycle Time

Individual burns were timed to determine cycle times for burning large amounts of propellant (Table 2). The first burn was an instructional event, so only the finish time for that burn was recorded. As mentioned above, the limiting factor for the cycle time for these tests was the temperature of the lifting handles of the bonnet. This is addressed in the final design modifications. The total time to burn all the propellant was about 1h10m minutes, or about 12 minutes per burn. Of the 12 minutes, seven minutes were consumed in allowing the pan to cool down so the bonnet could be safely removed without incurring discomfort on bare hands.

Table 2: Timing of burn events on 14 August 2015

Load	Loading	Burn	Finished
1	—	—	1006 h
2	1015 h	1017 h	1020 h
3	1025 h	1027 h	1030 h
4	1040 h	1041 h	1045 h
5	1052 h	1056 h	1056 h
6	1105 h	1107 h	1110 h

Cool down times were estimated from the infrared camera images taken of the burn (Appendix B). The post-burn imaging was limited by the storage capacity of the camera, so regression analysis was used to extrapolate the data beyond the last image. Cool down time to 40° C is estimated to be seven minutes.

Original Mass of Analytes

Only charges 6 and 7 were available for the tests. Using component data from MIDAS, charge 6 weighs 255 g, 250 g of which is M1 single base propellant. Charge 7 weighs 413 g, 405 g of which is M1 propellant. M1 propellant contains 10±2% DNT. Thus in charge 6 there is 25 g of DNT and in charge 7 there is 40 g of DNT. There were approximately 690 of each charge consumed during testing, for a total mass of M1 propellant of 458 kg. Total DNT mass in the M1 propellant used for the tests was 40.7 kg. Lead carbonate, at 1% of the propellant mass, is the only non-combustible component of the formulation. It is used as a burn regulator agent for the propellant and is very toxic, described as a Class 2B carcinogen and harmful to female reproduction. Lead makes up approximately 89% of the mass of the lead carbonate, resulting in a total mass of lead of approximately 4 kg in the charges used for the tests.

Energetics in Soil

Soil samples were analyzed for both 2,4- and 2,6-DNT. Table 3 summarizes the results (Appendix C contains a more complete data set). The data shows that DNT contamination existed at the burn pan location prior to the test. The concentrations are of the same magnitude as we have found previously at this firing point and at other burn pan test locations. There is no significant difference in concentrations before and after the test burn for the DNT compounds, with overlap in the pre- and post-burn data. It is likely that the burning of the grass and the extreme radiant heat from the multiple burns reduced the mass of any DNT that may have been expelled from the pan as well as any that resided on the soil prior to the tests. These results are consistent with data from the previous two tests with burn pans on the soil.

Table 3: Soil concentrations of DNT before and after test burn (mg/kg)

		0 to 3 m Annulus				3 to 6 m Annulus			
		Incrs.	Mass (g)	2,4-DNT	2,6-DNT	Incrs.	Mass (g)	2,4-DNT	2,6-DNT
Pre-burn	Rep 1	42	694	3.0	0.08	76	1364	4.5	0.15
	Rep 2	44	704	5.4	0.15	40	768	3.0	0.11
	Rep 3	46	763	5.6	0.18	81	1696	5.8	0.18
	Mean	44	720	**4.7**	**0.14**	66	1276	**4.4**	**0.15**
Post-burn	Rep 1	52	792	4.5	0.14	81	1686	5.9	0.25
	Rep 2	59	872	5.6	0.17	50	998	3.0	0.09
	Rep 3	54	872	3.8	0.12	51	988	2.9	0.09
	Mean	55	845	**4.6**	**0.14**	61	1224	**3.9**	**0.14**

Mass and Energetics in Pan

Residues retained within the pan were measured after drying and the masses broken out as depicted in Table 4. The initial charge mass of the burn was 458.4 kg. The mass of the residues was 99 g (Figure 8). The efficiency of the burn in reducing the combustible mass was 99.98%. The 0.02% of combustible mass remaining after the initial burn in the pan is less than the 0.1% goal of the project. Thus the system met the target efficiency goal. The amount of DNTs found in the ash is depicted in Table 5. The data are presented in three ways: as a total recovered mass, as a percent of the ash remaining in the pan, and as a percent of the estimated mass of DNT in the charges prior to burning. The percent of residue mass is important as it has implications for transport and disposal. The 0.33% concentration of DNT in the ash is quite low, allowing transport on public roads. The percentage of the original mass of DNT remaining in the pan is also quite low, much lower than found after previous burn tests. There is no ESTCP performance goal for DNT in the pan.

Table 4: Mass reduction from the propellant burn (from burn pan)

Component	Pre-burn Mass (Kg)	Mass recovered: False Bottom (g)	Mass Recovered from Base (g)	Percent of Pre-burn Mass Remaining
Charges	458.4			
Residues		41	58	0.02%

Figure 8: Residues collected from false bottom of pan following completion of testing.

Table 5: Energetics in final pan residues

	Final Total Mass (g)	Mass of 2,4-DNT (g)	Mass of 2,6-DNT (g)	Percent of Residue Mass	Percent of DNT mass
In False Bottom	41	0.054	BDL*	0.13%	0.0001%
In Pan	58	0.280	0.0023	0.48%	0.0007%
Overall	99	0.330	0.0023	0.33%	0.0008%

*BDL: Below the detection limit of the analytical instrumentation.

Lead Measurements

The samples of the soil surrounding the burn pan did not indicate a consistent increase in the concentration of lead following the burn. Subsamples of all the ground soils were shot with an X-Ray Florescence (XRF) instrument (Niton 700 series) for lead content. Exposure time for each sample was determined by the stabilization of the standard deviation displayed on the instrument. Minimum recommended analysis time is 60 nominal seconds. The detection limit for the Niton 700 is ≈20 ppm for lead. Results are shown in Table 6. Pre-burn propellant grains were removed from a Charge 7 propellant bag and shot with the Niton XRF. Readings were below the 20 ppm lead detection limit of the instrument. Only one sample indicated a slight elevation in soil lead concentration.

Table 6: Results of soil lead concentration investigation using XRF

Sample	Reading #	Analysis Time (s)	Pb Conc. (ppm)
RCRA Standard[1]	144	103	480 ±19
RCRA Standard	147	104	490 ±19
Pre-demonstration samples			
15FPSally-01	148	88	23 ±6.4
15FPSally-02	149	151	15 ±4.7
15FPSally-03	150	88	24 ±6.6
15FPSally-04	151	97	14 ±5.9
15FPSally-05	152	98	17 ±5.8
15FPSally-06	154	83	17 ±6.5
	Mean	100	18
Post-demonstration samples			
15FPSally-07a[2]	140	85	20 ±6.2
15FPSally-07b	141	88	30 ±5.9
15FPSally-07c	142	103	28 ±6.1
15FPSally-08	156	90	15 ±6.1
15FPSally-09	157	93	23 ±6.3
15FPSally-10	158	121	18 ±5.2
15FPSally-11	159	82	19 ±6.5
	Mean[4]	96	20
15FPSally-12	160	105	100 ±7.8
15FPSally-12 Dup[3]	161	95	98 ±8.1

[1] USEPA Resource Conservation and Recovery Act standard sample (Concentration ≈500 ppm)
[2] Three separate subsamples of 15FPSally-07
[3] Duplicate of the same subsample of 15FPSally-12
[4] Means of samples 15FPSally-07 through -11

This area is used as a small arms battle course (lead bullets) and was a firing position for the artillery unit just prior to our tests. The Charge 5 propellant bag, which contains lead foil, was used for all rounds fired from this position. Either of these activities may be the source of the single elevated detection of lead. All samples were well below the EPA recommended exposure level of <400 ppm.

The ash was examined with both the Niton instrument and a newer Innov-X XRF instrument. Results are presented in Table 7. The Niton results averaged 14,000 ppm (n=2) and the Innov-X results averaged 22,000 ppm. Both instruments were set up for soil, so the ash measurements are qualitative, indicating a high concentration of lead but not able to return a true concentration. Samples have been sent out of the lab for further analysis on metals analysis instrumentation.

Table 7: Qualitative concentrations of lead in the burn pan ash residues

Sample	Reading #	Analysis Time (s)	Pb Conc. (ppm)
Niton 700 Series XRF			
15FPSally-Ash	165	103	14K±95
15FPSally-Ash Dup.	166	152	15K±79
	Mean	128	14,000
Innov-X XRF			
15FPSally-Ash: Rep 1	2	120	17K ±130
15FPSally-Ash: Rep 2	3	120	23K ±180
15FPSally-Ash: Rep 3	4	120	23K ±180
15FPSally-Ash: Rep 4	5	120	23K ±180
	Mean[4]	120	22,000
15FPSally-Ash: Bulk	6	120	17K ±140

Quality Assurance

Three blank samples were ground consisting of 500g of Ottawa sand (Ottawa, IL, USA) each. One was done prior to grinding the field samples, one half way through the samples, and one after all the field samples were completed. No DNT was found in any of the samples upon analysis.

A 10-g soil blank was run using Lebanon (NH) landfill sand, which we use as a standard soil for extraction blanks. No analytes were detected after extraction and analysis.

Replicate subsamples were taken from two of the ground field samples and analyses preformed. Triplicate analyses were performed on a pre-burn sample (15FPSally-03). The 2,4-DNT concentrations for these replicates range from 3.1 to 3.7 mg/kg with a mean concentration of 3.5 mg/kg. For 2,6-DNT, the range is 0.10 to 0.12 mg/kg with a mean of 0.11 mg/kg. The RSD 9% for the 2,4-DNT and 9% for the 2,6-DNT. Seven subsamples were taken from the sample on which the matrix spike was performed (15FPSally-07). For 2,4-DNT, the concentrations ranged from 3.0 to

3.7 mg/kg with a mean concentration of 3.3 mg/kg and a median concentration of 3.2 mg/kg. For 2,6-DNT, the range is 0.10 to 0.14 mg/kg with a mean and median value of 0.12 mg/kg. The RSD is 8% for the 2,4-DNT and 13% for the 2,6-DNT. **Table 8** summarizes this data.

Table 8: Results of laboratory control samples

Sample	Subsamples	2,4-DNT (mg/kg)	2,6-DNT (mg/kg)
15FPSally-03	3	3.7	0.12
(Pre-burn 0-3 m)		3.1	0.10
		3.6	0.11
	Mean	3.5	0.11
	STD DEV	0.31	0.01
	RSD	9%	9%
15FPSally-07	7	3.0	0.13
(Post-burn 0-3 m)		3.2	0.14
		3.7	0.14
		3.2	0.11
		3.4	0.11
		3.5	0.13
		3.0	0.10
	Mean	3.26	0.12
	STD DEV	0.26	0.02
	RSD	8%	13%

Two laboratory control spikes were run, with a target concentration of 1 mg/kg of 2,4-DNT and 2,6-DNT in a blank soil (Lebanon landfill sand). Recovery rates following extraction and analysis are shown in **Table 9**.

Table 9: Results of laboratory control samples

Sample	2,4-DNT (mg/kg)	% Recovery	2,6-DNT (mg/kg)	% Recovery
LCS-1	0.99	99%	0.97	97%
LCS-2	0.99	99%	0.99	99%

A matrix spike was conducted on one of the samples (15FPSally-07: See Table 8). The mean concentration prior to spiking was 3.26 mg/kg 2,4-DNT. Based on seven replicates, the 95% confidence limit for this mean is ±0.24 mg/kg. Therefore, the target concentration of the matrix spike ranges from 4.0 to 4.5 mg/kg. Duplicate samples were analyzed and were found to be within the 95% confidence range, indicating 100% recovery (**Table 10**).

Table 10: Results of matrix spike samples

Sample	2,4-DNT (mg/kg)	2,6-DNT (mg/kg)
15FPSally-07 (7 reps)	3.26	0.12
15FPSally-07Spike-a*	4.23	1.12
15FPSally-07Spike-b*	4.25	1.13

*Duplicate samples from 15FPSally-07

Finally, we looked at the mass per increment (mass/incr.) of soil collected by the various sampling teams. We had not looked at this statistic before and felt it may be useful in gauging the consistency between sampling teams. This is important because uniform increments are necessary to reduce the sampling error. Little variability is found between samples by the same sampler and between samplers (**Table 11**). The means and medians for both sets of samples match, indicating normally distributed data. Both the standard deviations (STD DEV) and the relative standard deviations (RSD) for both data sets are low.

The average mass per increment for the 0–3 m DU samples ranged from 18 g/ incr. to 21 g / incr., with a mean value of 20 g/incr., a median value of 20 g/incr., and a relative standard deviation (RSD) of 5%. For the 3–6 m DU, the range of values was 15 to 17 g/incr. with a mean of 16 g/incr., a median of 16 g/incr., and RSD of 5%.

Table 11: Mass per increment for soil samples taken around burn pan

Sample	Sampler	Mass/Incr (g)	Sample	Sampler	Mass/Incr (g)
0-3 m DU			3-6 m DU		
15FPSally-01	MRW	18	15FPSally-04	CES	16
15FPSally-02	MFB	19	15FPSally-05	SLJ	16
15FPSally-03	SAB	21	15FPSally-06	SLJ	17
15FPSally-07	SAB	20	15FPSally-10	CES	15
15FPSally-08	MRW	20	15FPSally-11	CES	15
15FPSally-09	MRW	19	15FPSally-12	SLJ	16
	Mean	20		Mean	16
	Median	20		Median	16
	STD DEV	1.1		STD DEV	0.73
	RSD	5%		RSD	5%

Comments

Test results were consistent with previous burn pan tests and indicate the system works as planned. Soil concentrations of the analytes were not significantly different after the burn from the baseline values determined from the pre-burn samples. If testing had occurred in winter, it is likely

some increase in analyte concentration on the ground would have been evident. The radiant heat of the burn, the ignition of the ground vegetation caused by the burn, and the ability of the kicked out bag material to burn out on dry soil would not have occurred in a snowy environment.

The sample increment study produced interesting results. One of the significant sources of sampling error, called materialization error, is caused by inappropriate sampling tool selection. An incorrect tool will result in inconsistent increment masses. With our tests, mean increment variability was reduced to <2 g, quite good for a mixed soil/vegetation medium of varying density. Soil moisture is a variable we did not measure but may be the cause of some of the variance. Testing demonstrated that the CRREL Multi-Increment Sampling Tool worked very well under our test conditions.

The QA results point to a well-conducted test with robust data. Replicate sampling results indicate properly ground samples and consistency of subsampling the ground samples. This is important because the proper grinding of soils containing propellant residues is difficult. Most propellants are nitrocellulose (NC) based, and the NC is very difficult to break down into fine particles.

The burn pan design has been finalized based on feedback from the demonstration participants. The system weight is now below 120 kg with a total weight of 119.3 kg (aluminum pan 41.7 kg, false bottom 43.1 kg, bonnet 34.5 kg). The handles have been moved to the lower frame of the bonnet for ease of access and to get them out of the hottest of the burn.

The performance and effectiveness of the burn pan met the ESTCP goals for these tests. The results point to a very effective system for the training of the troops. All outside participants and observers agreed that the system was a very useful tool from their perspectives. The training unit officers stated the burn pan was a great enabling tool for training of their soldiers, the ITAM officer saw it as a valuable tool for protecting the environment, and the Range officer saw its value in being able to better control the burning of the propellants. The Range Manger requested that the pan be turned over to him and that CRREL provide USARAK with an estimate for two to three more units for use in the future.

Summary

The test and demonstration of the CRREL HTU portable burn pan was very successful. All project goals that were relevant were achieved or succeeded. The final volume of the residues from the burning of the 458 kg of propellant charges was less than a liter and contained only 4.3 mg of DNT. There was no significant difference in DNT concentrations in the soil surrounding the pan before and after the test burn. Lead in the propellant formulation will need to be further examined to determine if the ash remaining in the pan will need to be considered hazardous. The sponsoring facility representatives, Mr. Steve Thurmond and Ms. Ellen Clark, agreed to keep and use the burn pan for further training missions and requested additional pans if available. The training unit Commander and Command Sergeant Major both felt the pan was a very valuable additional training tool for their unit and looked forward to using it more during their training deployment at Donnelly Training Area.

The portable burn pan is efficient, easy to use, and can be used as a training aid, all the while helping maintain range sustainability by greatly reducing ground contamination and allowing the efficient collection and control of toxic residues. At the Donnelly Training Area, all parties agreed that it is a welcome addition to their range and environmental toolbox.

User Feedback

User feedback was an essential component of the testing at DTA. This feedback will be used to refine the equipment design and develop the protocol for the use of the pans. The following is feedback obtained at DTA from the interested parties as well as some observations from the CRREL test staff.

- **USARAK ITAM Manager (Ellen Clark)**
  - Liked the concept very much
  - Should be integrated into range management practices
- **Range Commander (Steve Thurmond)**
  - Concept seems to work quite well
  - Would like to keep pan and utilize it for training
  - Would like at least two more additional pans
- **Training Unit (2/377th PFAR)**
  - Handles on bonnet need to be lower for short guys
  - Really like the ability to burn propellant close to firing points
  - Need to reduce the sides of the false bottom to avoid overloading the pan

Other Possible Improvements (CRREL)

- Don't need the door on the bonnet any more – remove from next iteration
- Beef up the mounting of the legs on the base

After-action Tasks (CRREL)

- Modify drawings with changes
- Send a set of drawings to interested parties
- Test report copies to ESTCP, DTA Range, and ITAM program manager

Suggested Procedure for the Utilization of the Portable Burn Pan on Ranges

1. Burn pan signed out and transported from holding facility to firing point
2. Location of burn pan demarcated based on input from Range or RSO/OIC (Factors: Safety, fire hazard, levelness, distance from environmentally sensitive areas such as surface water)
3. Burn pan placed at demarcated location (Cover with tarp if raining or rain predicted)
4. Fire suppression equipment (Class A extinguisher, spray tank) placed 100 m from burn pan
5. Excess propellant charges are generated through training (Keep all charges dry)
6. At a break in firing or cessation of training, assign propellant burn duties to two to four soldiers
7. Move propellant bags from firing positions to ≈100 m from burn pan
8. Remove the tarp (if present) and perforated bonnet from the base of the burn pan
9. Load the burn pan with charges (Maximum height of the charges is the top of the inner perforated screen on the false bottom)
10. Cut open sufficient propellant bags (3 minimum) and place a thin layer of grains in the initiation slider mechanism. Pour remaining grains on top of the propellant bags at the end of the slider at the loaded false bottom
11. Replace the bonnet on the pan
12. Position one soldier at initiation slider end of burn pan
13. Soldier lights the propellant grains, confirming ignition
14. Walk 50 m minimum from the burn pan: Observe the burn
15. When the burn is complete, wait one minute and approach the pan to verify
16. Wait for cool down (2 – 5 minutes) before the next task
17. If there are more propellant charges to burn, reinitiate the sequence at Step 9
18. If this is the final burn, remove the bonnet and inspect the pan for propellant or damage
19. (Optional) Scrape up the residues. Place the residues in a heavy polyethylene bag. Label, tag, and ty-wrap the residues bag (Date, type of propellant, training unit, OIC).
20. Check the temperature of the pan. Replace the bonnet and tarp on the burn pan.
21. Return the burn pan (and residues, if collected) to the transport vehicle
22. Transport the burn pan to the holding facility
23. Turn in residues if collected

Appendix A: Photo sequence of a burn

The following sequence of images depicts the sequence of steps for conducting a propellant burn.

1) Setting up a burn location (flags are for pre- and post-burn sampling, not necessary during training exercise burns)

2) Preparing to unload pan

3) Pre-burn operational briefing

4) Loading propellant into pan

5) Spreading out charges

6) Cutting charge bags for initiation

7) Pre-burn inspection

8) Primed initiation slider

9) Igniting grains in slider

10) Initiation slider grains burning

11) Opened propellant charges burning

14) Propellant charges fully engaged

15) Start of burn out

12) Propellant charges initiating

13) Propellant charges burning

16) Propellant load burning out

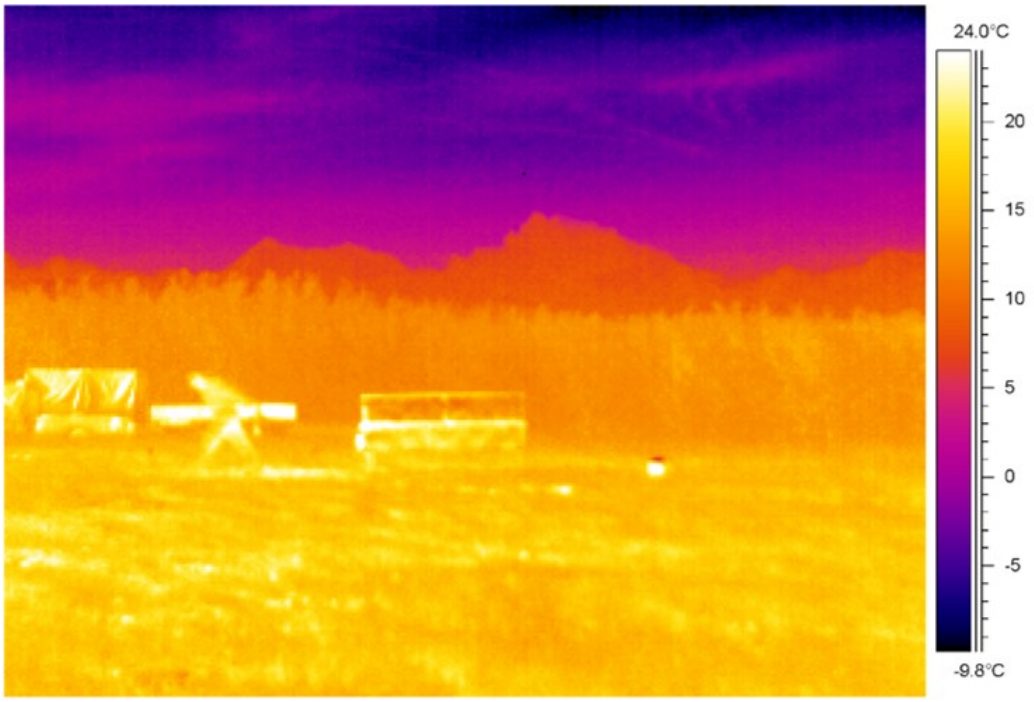
17) End of burn (≈8 seconds)

18) Post-burn Inspection of pan

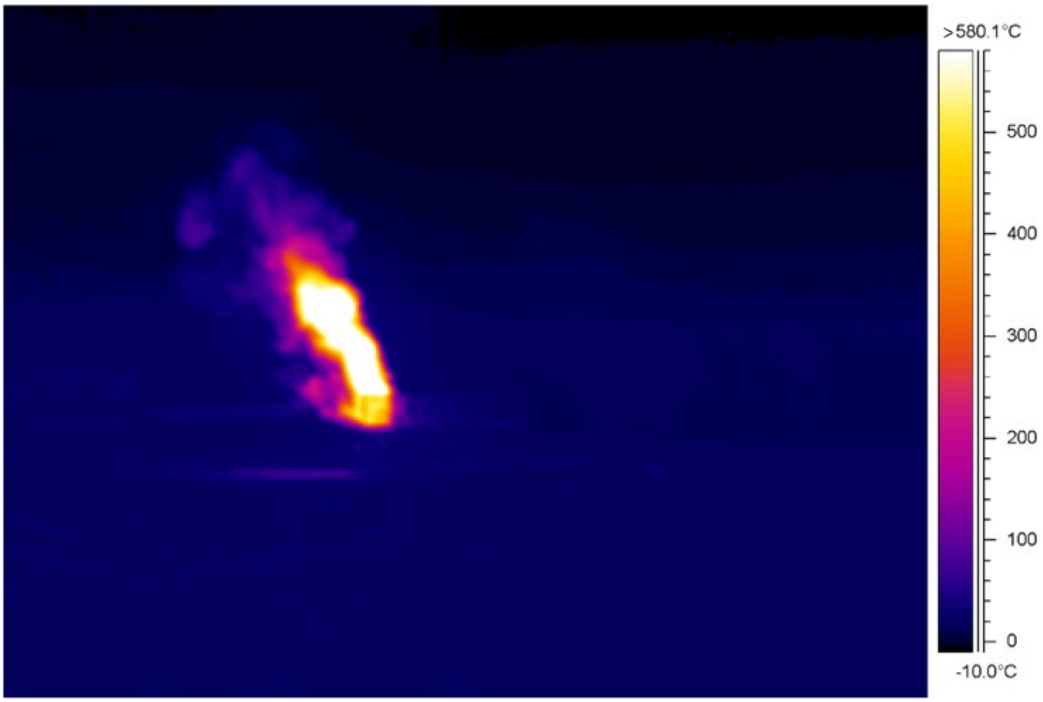
19) Site at end of 6 burns (458 kg) Green rectangle was pan location

Appendix B: IR Camera Sequence of a Burn

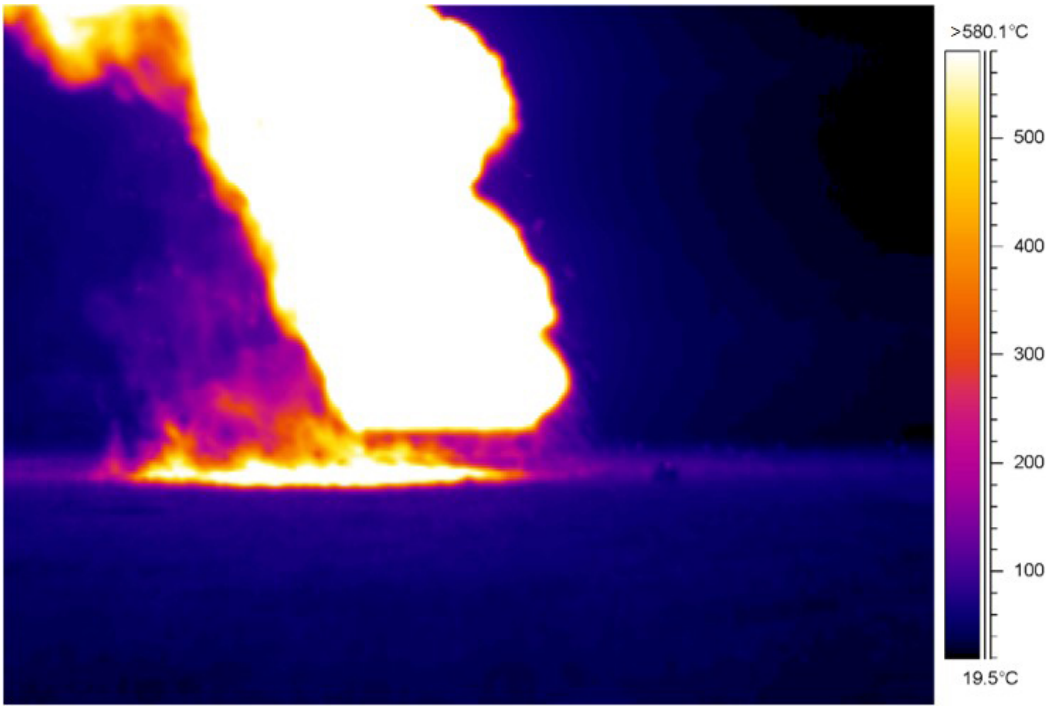
This sequence is a series of screen shots from an infrared video of the training burn of 89 kg of M1 propellant at the Donnelly Training area in Alaska in August of 2015. Note the varying temperature scale to the right of each thermal image. This series of images captures the second of six burns of the training mission. Background temperature at the site was about 20° C. Time in m:ss.



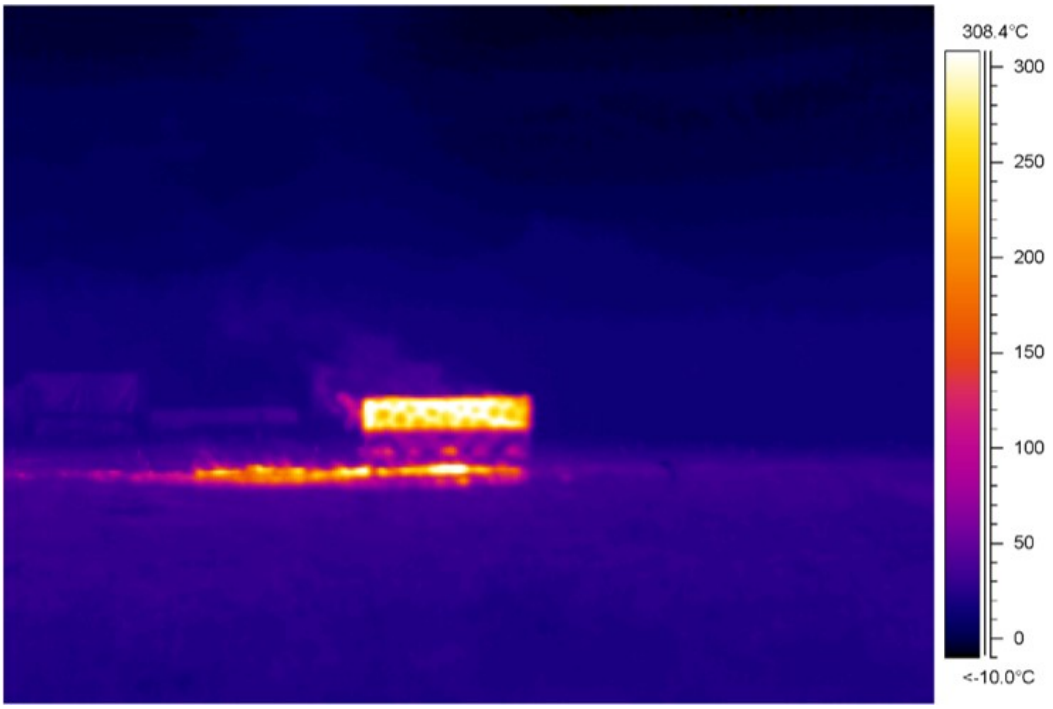
B-1. 0:00 – Initiation



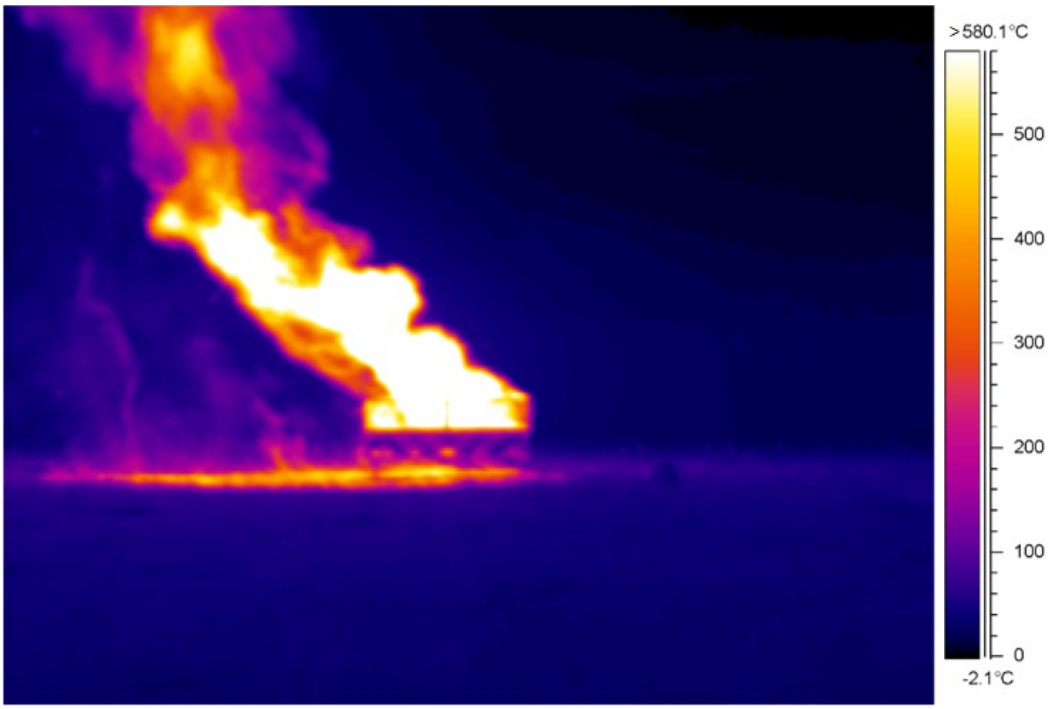
B-2. 0:23 – Charges ignite



B-3. 0:30 – Peak of burn



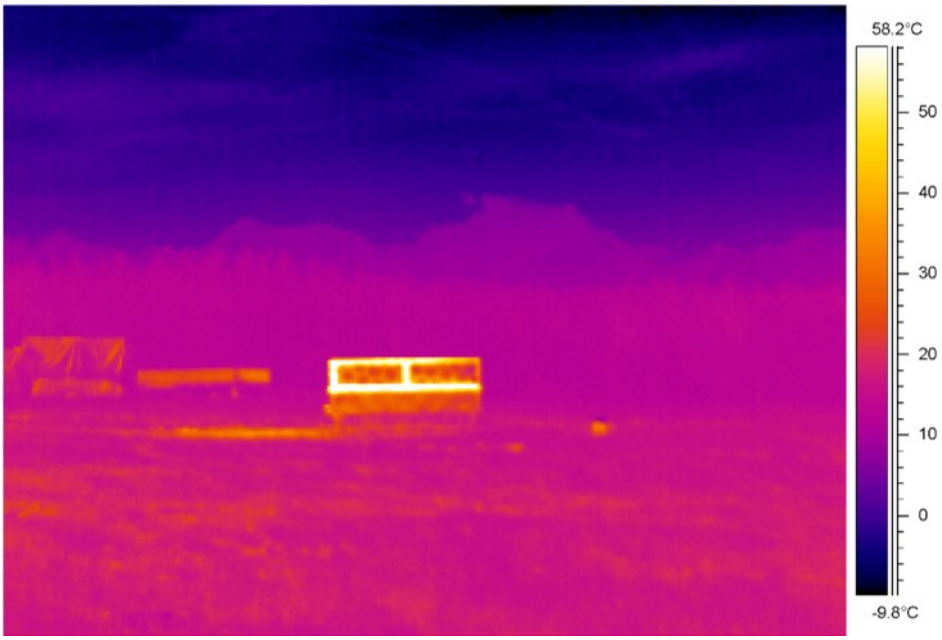
B-5. 0:44 – End of burn. 310°C maximum temperature of system: Start of cool down (0 sec)



B-4. 0:34 – Burning out

B-6. 1:14 – Cool down: 150°C (30 s)

B-7. 1:44 – Cool down: 95°C (60 s)



B-8. 3:19 – Cool down: 58°C. End of IR imaging sequence. (155 s)

Appendix C: Analytical data for soils

Table B.1. Pre-analysis sample processing data

Bag ID	Sample ID	Rep	Sampler	Bagger	Date Collected	Incr. Depth (cm)	Core ø. (cm)	# of Incrs	Grinder	Date Ground	Date Subsampled	Date Extracted	Mass (g) Dried	Mass (g) Ground*
15DTA Pre Burn 3-6m Rep1	15FPSally_01	1	MRW	SAB	8/13/15	3	3	76	S. Jarvis	9/28/15	9/28/15	9/29/15	1364.0	1354.2
15DTA Pre Burn 3-6m Rep2	15FPSally_02	2	MFB	MEW	8/13/15	3	3	40	S. Jarvis	9/28/15	9/28/15	9/29/15	767.9	760.5
15DTA Pre Burn 3-6m Rep3	15FPSally_03	3	SAB	MRW	8/13/15	3	3	81	S. Jarvis	9/28/15	9/28/15	9/29/15	1695.9	1676.2
15DTA Pre Burn 0-3m Rep1	15FPSally_04	1	CES	SLJ	8/13/15	3	3	42	S. Jarvis	9/28/15	9/28/15	9/29/15	694.0	688.2
15DTA Pre Burn 0-3m Rep2	15FPSally_05	2	SLJ	CES	8/13/15	3	3	44	S. Jarvis	9/28/15	9/28/15	9/29/15	704.4	698.7
15DTA Pre Burn 0-3m Rep3	15FPSally_06	3	SLJ	CES	8/13/15	3	3	46	M. Bigl	9/29/15	9/29/15	9/29/15	762.5	761.0
15DTA Post Burn 3-6m Rep1	15FPSally_07	1	SAB	MEW	8/14/15	3	3	81	Jarvis/Bigl	9/29/15	9/29/15	9/29/15	1686.0	1658.1
15DTA Post Burn 3-6m Rep2	15FPSally_08	2	MRW	SAB	8/14/15	3	3	50	M. Bigl	9/29/15	9/29/15	9/29/15	997.9	993.6
15DTA Post Burn 3-6m Rep3	15FPSally_09	3	MRW	SAB	8/14/15	3	3	51	M. Bigl	9/29/15	9/29/15	9/29/15	988.0	983.4
15DTA Post Burn 0-3m Rep1	15FPSally_10	1	CES	SLJ	8/14/15	3	3	52	M. Bigl	9/29/15	9/29/15	9/29/15	792.4	783.7
15DTA Post Burn 0-3m Rep2	15FPSally_11	2	CES	SLJ	8/14/15	3	3	59	M. Bigl	9/29/15	9/29/15	9/30/15	871.5	869.8
15DTA Post Burn 0-3m Rep3	15FPSally_12	3	SLJ	CES	8/14/15	3	3	54	M. Bigl	9/29/15	9/29/15	9/30/15	872.5	870.0

*Ground on a LabTech Essa-2P puck mill at <500 g lifts for 5x60 seconds with 5-minute cool-down between grinds.

Table B.2. Post-demonstration analytical results

Vial Label	HPLC Analysis	2,4-DNT	2,6-DNT	Mass/Incr.	Sampled Area (m2)	Area of DU (m2)	2,4 DNT In sample (mg)	2,6 DNT In sample (mg)	Total DNT mass in Sample (mg)	Est. Mass in DU (mg)	Mass in DU (g)	Avg Mass in DU (g)	Average Mass/m2
15FPSally_01	30-Sep-15	3.29	0.11	18	0.054	26	4.5	0.15	4.6	2200	2.2		
15FPSally_02	30-Sep-15	3.94	0.15	19	0.028	26	3.0	0.11	3.1	2900	2.9		
15FPSally_03	30-Sep-15	3.46	0.11	21	0.057	26	5.8	0.18	6.0	2700	2.7	2.6	0.10
15FPSally_04	30-Sep-15	4.37	0.12	16	0.030	87	3.0	0.08	3.1	9100	9.1		
15FPSally_05	30-Sep-15	7.68	0.22	16	0.031	87	5.4	0.15	5.5	15,000	15		
15FPSally_06	30-Sep-15	7.33	0.23	17	0.033	87	5.6	0.18	5.8	15,000	15	13	0.15
15FPSally_07	30-Sep-15	3.57	0.15	20	0.057	26	5.9	0.25	6.2	2800	2.8		
15FPSally_08	30-Sep-15	3.00	0.09	20	0.035	26	3.0	0.09	3.1	2300	2.3		
15FPSally_09	30-Sep-15	2.92	0.09	19	0.036	26	2.9	0.09	3.0	2100	2.1	2.4	0.092
15FPSally_10	30-Sep-15	5.70	0.18	15	0.037	87	4.5	0.14	4.6	11,000	11		
15FPSally_11	1-Oct-15	6.48	0.19	15	0.042	87	5.6	0.17	5.8	12,000	12		
15FPSally_12	1-Oct-15	4.37	0.14	16	0.038	87	3.8	0.12	3.9	9000	9.0	11	0.12

Table B4: Post-burn pan ash extract data

Sample ID / Vial Label	Injec-tion	Sampler	Bagger	Date Collected	Date Extracted	Mass (g) Dried	Bag ID	Mass (g) Dried	HPLC Analysis	Conc.(mg/kg) 2,4-DNT	Conc.(mg/kg) 2,6-DNT	Est. Mass (mg) 2,4-DNT	Est. Mass (mg) 2,6-DNT
Post-Burn: False Bottom	1	MFB	MEW	8/14/15	10/6/15	40.66	15DTA Post Burn False bottom	40.66	8-Oct-15	1340	<0.04	54	0
Post-Burn False Bottom Dup	2	MFB	MEW	8/14/15	10/6/15	40.66	15DTA Post Burn False bottom	40.66	8-Oct-15	1320	<0.04	54	0
Post-burn: Out. False Bottom	1	MFB	MEW	8/14/15	10/6/15	58.20	15DTA Post Burn Alu (pan) bottom	58.20	8-Oct-15	4870	39.6	280	2.3
Post-burn: Out. False Bottom Dup	2	MFB	MEW	8/14/15	10/6/15	58.20	15DTA Post Burn Alu (pan) bottom	58.20	8-Oct-15	4850	41.5	280	2.4

Table B4: QA data tables – Blanks and spikes

Sample ID	Sample Dp. (cm)	Inc. Core ø (cm)	# of Incr	Grinder	Date Ground	Date Subsampled	Date Extracted	Vial Label	Mass (g) Ground	HPLC Analysis	Concentration* in Soil (mg/kg) 2,4-DNT	Concentration* in Soil (mg/kg) 2,6-DNT
Grinding Blanks												
15FPSally Pre-Grind	-	-	-	S. Jarvis	9/28/15	9/29/15	9/29/15	15FPSally Pre-Grind Blank	-	30-Sep-15	<0.04	<0.04
15FPSally Mid-Grind	-	-	-	S. Jarvis	9/29/15	9/29/15	9/29/15	15FPSally Mid-Grind Blank	-	30-Sep-15	<0.04	<0.04
15FPSally Post-Grind	-	-	-	M. Bigl	9/30/15	9/30/15	9/30/15	15FPSally Post-Grind Blank	496.2	1-Oct-15	<0.04	<0.04
Matrix Spikes												
15FPSally_07	3	3	81	Jarvis/Bigl	9/29/15	9/29/15	9/29/15	15FPSally_07	1658.1	30-Sep-15	3.26	0.12
15FPSally_07 MS	3	3	81	Jarvis/Bigl	9/29/15	9/29/15	9/29/15	15FPSally_07 MS	1658.1	30-Sep-15	4.23	1.12
15FPSally_07 MSD	3	3	81	Jarvis/Bigl	9/29/15	9/29/15	9/29/15	15FPSally_07 MSD	1658.1	30-Sep-15	4.25	1.11
Laboratory Control Spikes												
15FPSally_LCS1 10mg/L	-	-	-	-	-	9/29/15	9/29/15	15FPSally_LCS1 10mg/L	-	30-Sep-15	0.99	0.97
15FPSally_LCS2 10mg/L	-	-	-	-	-	9/29/15	9/29/15	15FPSally_LCS2 10mg/L	-	30-Sep-15	0.99	0.99

Preparing to load the burn pan for the first test and demonstration burn, Donnelly Training Area, Alaska, 14 August 2015.

CRREL's DTA Burn pan demonstration crew: Marianne Walsh, Stacey Jarvis, Michael Walsh, Matt Bigl, Sam Beal, and Charlie Smith